Quadripartite Advisory Publication
(QAP)

Number 149 Edition 1

TERRAIN RESOLUTION AND CONTENT REQUIREMENTS FOR COMBAT MODELS

DECLARATION OF ACCORD

1. Introduction

The information contained in this Quadripartite Advisory Publication introduces those areas of a specialized nature where standardization is not possible but the identification and exchange of which achieves substantial gains in mutual understanding and co-operation.

2. Scope

All Armies employ combat simulations for operational research or training applications. A common aspect of these simulations is the requirement to model the effects of the terrain on combat. This Quadripartite Advisory Publication recommends to Armies the degree of fidelity with which the spectrum of terrain features should be modelled, as a function of the class of the combat model/simulation.

3. Background Continuity and Related Documents

The Quadripartite Working Group on Army Operational Research has maintained a focus on digital terrain data support to operational research models through Special Working Parties on Terrain Descriptions (SWP TD), Terrain Analysis (SWP TERA), and Combat Modelling of the Effects of Terrain (SWP CMET). Additional details of the supporting proposals and discussions that led up to this publication can be found in the published reports of SWP CMET for their May 1992 and April 1994 meetings.

4. Amendment

The contents of this QAP should be reviewed as appropriate by contributing Armies, to reflect developments in national practices, and to maintain its currency.

5. Use

The information contained in this QAP should, whenever possible, be used by Armies to improve the level of standardization on digital terrain representations in combat models.

9th December 1996

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TABLE OF CONTENTS

Page

QUADRIPARTITE ADVISORY PUBLICATION No. 149
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INTRODUCTION

1. Combat models are necessarily a simplification and abstraction of modern air/land combat. Depending on the anticipated applications of the model, the elements of combat will be represented with varying degrees of fidelity. Some elements may not be modelled at all.

2. This holds true for the representation of terrain within combat models, as well - especially digital terrain representations employed to support computerized combat models. One cannot hope to simulate the effect of every molecule in the combat environment. Those terrain factors which influence the combat operations significantly (eg. factors which influence intervisibility and mobility) should be accounted for in as robust a fashion as possible. But many lesser factors will be represented more coarsely, or not at all.

3. Which terrain factors should be represented and to what level of detail depends on the type of combat model and the nature of the problems to which it is applied. The modeller must also acknowledge the problems associated with production of the terrain data bases. A more detailed terrain representation will demand more time and resources to generate.

AIM

4. The aim of this Quadripartite Advisory Publication (QAP) is to make recommendations to the combat modelling communities within the Armies on which terrain factors should be represented in various classes of combat models, and on the degree of fidelity with which they should be represented.

CLASSES OF COMBAT MODELS

5. Combat models tend to fall into classes based on the size of the forces being simulated and the nature of the problems being investigated. For the purposes of this analysis **four** distinct classes have been established to cover the combat modelling spectrum - *Theater, Division/Corps, Battalion/Brigade,* and *Company* ("few-on-few" level). These are presented in Table I.

6. Note that the term "combat model" includes both interactive wargames and automated simulations (where the tactical decision making may be automated, usually in a rule-based fashion). Of the combat model examples presented in Table I, Janus, the UK Divisional Wargame (DWG), and CAEN are interactive wargames. The remainder are automated combat simulations.

TABLE I
CLASSES OF ARMY COMBAT MODELS

CLASS	EXAMPLE	APPLICATIONS
THEATER	TACWAR (US)	• Scenario and strategy development • Force structure analysis • Combat system mix optimization • War outcome prediction
DIVISION/CORPS	DWG (UK) EAGLE (US) VIC (US)	• Div/Corps scenario and tactics development • Analysis of combat system design alternatives • Combat system mix optimization • Battle outcome prediction
BATTALION/BRIGADE (Bn/Bde)	JANUS (US)* EDECSIM (UK) CASTFOREM (US)	• Bn/Bde scenario and tactics development • Bn/Bde procedures training • Analysis of combat system design alternatives • Combat system mix optimization
COMPANY (Coy)	CAEN (UK) COMSCAM (CA)	• Low level scenario and tactics development • Analysis of combat system and sub-system design alternatives

* All Armies employ versions of the US-developed Janus wargaming system.

7. These four broad classes cover the complete spectrum in terms of the size of forces represented. The length of combat simulated increases with the size of the forces. A *Company* model will simulate a duration of combat measurable in minutes. For *Battalion/Brigade* models the time span is in terms of hours. *Division/Corps* conflicts will span days, while *Theater* level conflict may unfold over weeks or months.

8. As the scale of the conflict - both the size of the forces involved and the duration - increases, there must necessarily be a change in the modelling approach taken. Small scale models will attempt to simulate combat in as much detail as possible. Individual combat systems and individual battlefield events will be modelled explicitly. In larger scale models, combat systems will be aggregated into companies, or battalions, or divisions, etc. The interactions between these aggregated units will be modelled in a less explicit form as well. Instead of "engineering" attrition by simulating each battlefield event, one would attempt to summarize the fighting potential of aggregated units and employ more broad attrition algorithms. The traditional Lanchester equations method is an example of the type of approach which the modeller may adopt.

9. Aggregation is necessary for a number of reasons. The primary reason is limitations imposed by computer and human resources. The computer power required to drive large numbers of simulated battlefield interactions in a reasonable time can be prohibitive. Especially demanding are line-of-sight (LOS) computations. Just maintaining an up-to-date picture of who can see whom on the battlefield can occupy the majority of the computational effort. As computer technology advances this should become less and less of a concern, but it is still a limiting factor on the size of forces which can be simulated.

10. Another factor driving aggregation is the requirement to represent battlefield decision making. Wargaming a large force (such as a corps) where players must "micro-manage" each system on the battlefield individually would demand an inordinate number of players. Automated simulations strive to replace game players with artificial intelligence (AI) modules. However, the larger the scale of combat, the more diverse tactics and strategies become, and hence the more difficult it will be to model battlefield decision making aspects.

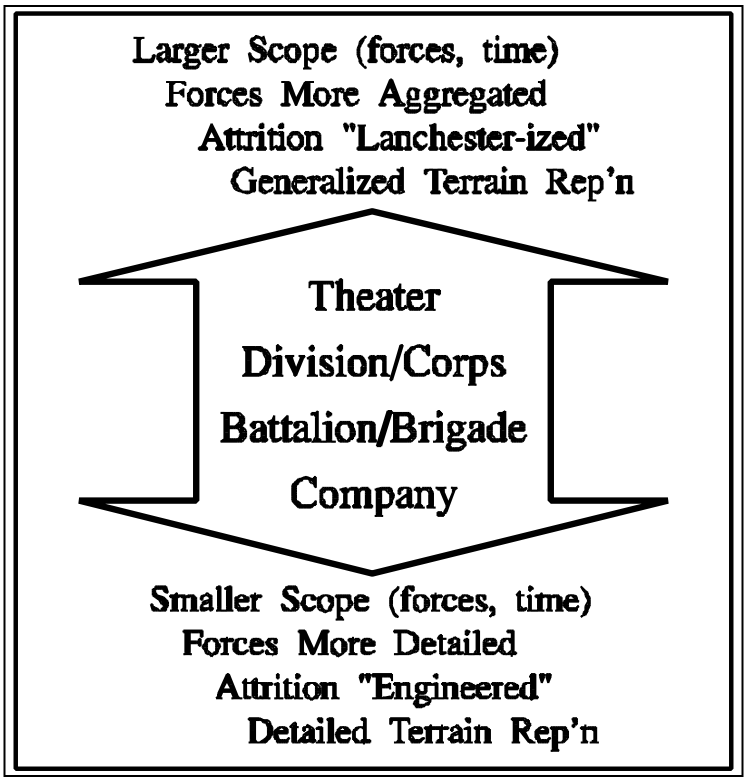

Figure 1
Combat Model Hierarchy

11. Terrain databases will support the combat models accordingly. Aggregation within the models lessens the demands on having explicit terrain representations. Detailed elevation and terrain feature models would give way to coarser and more generalized representations.

12. Figure 1 graphically summarizes the above discussions for the combat modelling spectrum adopted.

COMBAT MODEL APPLICATIONS

13. Combat models are applicable to a wide variety of Army Operational Research (AOR) problems. Each class of problem will carry slightly different requirements for terrain representation within the models. The rightmost column of Table I summarizes the applications most suitable to each of the four classes of combat models considered. These are outlined individually below.

14. Analysis of Combat System Design Alternatives. One of the major areas of application for combat models is in providing advice to Army requirements agencies on the relative battlefield value of alternative combat systems or sub-systems. One can simulate or play out common scenarios, substituting tank A for tank B, helicopter X for Y, etc, in order to assess the relative value of alternative systems in realistic combat environments. This can apply to any of the three lower levels of combat depending on the system being considered. Thus infantry systems would be analyzed at *Company* level, armour/anti-armour systems at *Battalion/Brigade* level, and indirect fire systems at *Division/Corps* level. In addition, command and control systems or surveillance and target acquisition systems might be assessed at all four levels.

15. If one is concerned with sub-system design options (eg. gun system A vs B, or target acquisition system X vs Y), then it may be worthwhile simulating smaller scale scenarios in more detail. This would call for the "few-on-few" or *Company* class of combat model.

16. Combat System Mix Optimization. Determination of the ideal mix of combat systems within a force is an area in which combat models can be effectively employed. One can investigate the relative battlefield effectiveness of different force mixes (eg. more direct fire systems, fewer indirect fire systems, etc.) by simulating them within specific scenarios. The scope of combat simulated must large enough to permit force interactions to occur on a broad enough basis. It the force mix alternatives being considered are focusing on direct fire weapon systems, then the *Battalion/Brigade* class of model may suffice. If the focus is on force support components, then perhaps a broader *Division/Corps* or *Theater* class of model would be best.

17. Force Structure Analysis. Each of the major components of an army formation - infantry, artillery, armour, logistical support, aviation, engineer support, etc. - is an essential ingredient to the effective functioning of that formation. The relative balance of these components is something that can be fine-tuned for specific missions or scenarios. Combat models can assist in assessing this balance. Higher level models - those at the *Division/Corps* or *Theater* level - are suitable for this type of analysis as they have the breadth of scope required to simulate the effects and interactions of most components.

18. Development of Scenarios, Military Strategy, and Tactics. The continuing evolution of new weapon systems, new threats, and new world conflict scenarios requires strategic and tactical doctrine to be regularly re-evaluated. Also, the application of such doctrine is as much an art as it is a science, making experience an essential ingredient in developing expert military strategists and tacticians. Therefore, the ability to simulate realistic conflict scenarios is an invaluable mechanism by which military staff can become trained in the art of the military strategist/tactician.

19. The *Theater* class of combat model contains the scope necessary to enable strategic plans and decisions to be exercised. *Division/Corps* and *Battalion/Brigade* models will enable the development and evaluation of military tactics at those respective levels.

20. At levels below battalion the scope is sufficiently small that field training exercises (FTXs) are perhaps the most effective means of training staff. However, field exercises are costly. Hence, combat models at the *Company*

and *Battalion/Brigade* level can serve as a useful complement to field exercises. By enabling plans to be screened and the exercises themselves replayed, maximum value can be obtained from the field time.

21. Procedures Training. Command post exercises (CPXs) are an excellent means of training military staff on operational procedures. Combat models at the *Battalion/Brigade* level and up offer the means to simulate an operational environment with sufficient realism to satisfy most staff procedures training requirements.

22. Battle Outcome Prediction. It is extremely valuable to be able to simulate anticipated combat operations before they actually occur. Although combat models will have at best rudimentary representation of some of the less tangible aspects of battle (eg. human factors, command and control), they can provide valuable insight into aspects of anticipated operations, especially of projected attrition levels. Potential problem areas can be identified and rectified before they become real problems. Proposed tactics can be evaluated. Combat models at *Battalion/Brigade* and *Division/Corps* can be used to assess outcomes of individual battles. Campaign or war outcome prediction can be assessed with *Theater* level models. It should be noted that the automation of engagement in combat models and the difficulties expressed above in modelling human factors makes the duration of battle difficult to quantify.

TERRAIN REPRESENTATION IN COMBAT MODELS

23. Any simulation of land combat must represent the terrain and/or its influence. The two major influences of the terrain are in the areas of intervisibility (IV) and mobility.

24. Terrain can be present in direct or indirect form. Traditional wargaming methods which employ simple maps or terrain boards are an example of indirect terrain representation. The effects of the terrain are manually interpreted and applied as the play of combat progresses. Most computerized combat models attempt to directly represent the terrain and its effects.

25. Terrain relief is traditionally represented on maps as sets of elevation contours. In combat models, however, relief is usually represented by a set of elevation posts over a rectangular grid. This "raster" approach is preferred over the "vector" representation by a set of contours for one major reason: speed of computation. The inherent ordering within a grid makes it relatively easy to interpolate spot elevations and to ascertain blockage between any two given points on or above the terrain. Intervisibility algorithms operating directly on the vector contours are orders of magnitude less efficient computationally. The major limitation associated with raster representation is that it forces a fixed grid spacing to be adopted.

26. Features present on the terrain can directly influence intervisibility and mobility, and are required to be represented within the combat model. Linear features such as roads, rivers, etc., clearly are best represented in vector form. Areal features such as vegetation, cross-country trafficability information, urban build-up, lakes, etc., can be represented either in vector (where vectors delineate the boundaries of the feature) or raster form (where parametric values are assigned to square terrain cells). The advantage of the raster format is that it is easier to process. The advantage of the vector format is that it imposes no resolution scale onto the data and generally has less demanding computer storage requirements.

TERRAIN RESOLUTION AND CONTENT REQUIREMENTS

27. There are hundreds of terrain features that can be recorded on cartographic products, both physical and digital. The objective of this analysis has been to sift through this extensive set, identify those with a notable impact on military operations, and assess the degree of fidelity with which these terrain features should be represented in the four classes of combat models identified. Through extensive discussions at the May '92 and April '94 meetings of the Special Working Party on Combat Modelling of the Effects of Terrain (SWP CMET) and subsequent review by correspondence, this task has been completed.

28. The results are presented as Table II. The required degree of representation (the "GEN RQMT" column) for each terrain feature was assessed for each of the four classes of combat model. Also presented for comparison purposes are the terrain representations associated with those existing combat models listed in Table I. It is hoped that such comparisons will prove useful in the future development and/or improvement of combat models.

Table III presents supporting discussion for the stated requirements in Table II. The military significance and modelling concerns of each terrain feature considered are summarized in thisTable.

TABLE II
TERRAIN RESOLUTION AND CONTENT REQUIREMENTS
FOR COMBAT MODELS

TERRAIN FEATURES	COMPANY			BATTALION/BRIGADE				DIVISION/CORPS				THI
	CAEN	COM-SCAM	**GEN RQMT**	JANUS	EDEC-SIM*	CAST-FOREM	**GEN RQMT**	UK DWG	EAGLE	VIC	**GEN RQMT**	TAC-WAI
AL FACTORS												
a is associated with map products cale of 1:	25K	50 K	**50 K**	50 K	50K	50K	**50 K**	50K	250K	250K	**250 K**	1M
izontal resolution: Minimum Ideal	10 m 10 m	100 m 12.5 m	**25 m** **5 m**	100 m 10 m	100 m 10 m	100 m 10 m	**100 m** **10 m**	500 m 500 m	100 m	100 m	**200 m** **50 m**	N/A
tical DTED resolution	.01 m	1 m	**0.1 m**	0.2 m	1 m	1 m	**1 m**	1 m	3 m	3 m	**3 m**	N/A
tical vegetation or urban height olution	.01 m	1 m	**0.1 m**	1 m	1 m	1 m	**1 m**	1 m	3 m	3 m	**3 m**	N/A
/ISIBILITY FACTORS												
ect computation of point-to-point using DTED?	Yes	Yes	**Req'd**	Yes	Yes	Yes	**Req'd**	Yes	No	No	**Pref'd**	No
ncealment: density attri-bute ting to IV horizon-tally through etation?	Yes	Limited	**Req'd**	Yes	Yes	No	**Req'd**	Part	Limited	No	**Pref'd**	No
ver: density attribute relating to IV n through vegetation?	Yes	Limited	**Req'd**	Yes	No	No	**Req'd**	Part	No	No	**Pref'd**	No
getation density factors for erent electromagnetic bands?	No	No	**Req'd**	No	No	No	**Req'd**	No	No	No	**Pref'd**	No
of vegetation density states for er/concealment	16	1	**64**	7	16	0	**32**	3	10	4	**16**	0
e trees represented?	Yes	Poss	**Req'd**	Poss	No	No	**Pref'd**	No	No	No	**Not Req'd**	No
sonal crop variation represented?	Yes	No	**Req'd**	No	No	No	**Pref'd**	No	No	No	**Not Req'd**	No
)AD MOBILITY												
nsity attribute relating to mobility ough vegetation?	Yes	User specifies mobility	**Req'd**	Yes	No	No	**Req'd**	Yes	Limited	Limited	**Req'd**	No
nsity factors for different vehicle sses?	Yes	"	**Req'd**	Part	No	N/A	**Req'd**	Yes	Limited	No	**Pref'd**	No
of vegetation density states for bility	8	"	**64**	8	0	0	**16**	9	Limited	4	**8**	0
tor indicating soil nature for ging?	No	"	**Req'd**	No	No	No	**Req'd**	No	No	No	**Pref'd**	No
ss-country mobility pre-processor uts required: Land use code Stem size Stem spacing Soil strength Seasonal variation Surface roughness Slope	No No No No No No Yes	" " " " " " "	**Req'd** **Req'd** **Req'd** **Req'd** **Req'd** **Req'd** **Req'd**	No No No No No No No	No No No No No No No	Yes Yes Yes Yes Yes Yes Yes	**Req'd** **Req'd** **Req'd** **Req'd** **Req'd** **Req'd** **Req'd**	No No No No No No No	Yes Pref'd Pref'd Pref'd Pref'd Pref'd Pref'd	Yes No No No No No No	**Req'd** **Pref'd** **Pref'd** **Pref'd** **Pref'd** **Pref'd** **Req'd**	No No No No No No No

TERRAIN FEATURES	COMPANY			BATTALION/BRIGADE				DIVISION/CORPS				THI
	CAEN	COM-SCAM	**GEN RQMT**	JANUS	EDEC-SIM*	CAST-FOREM	**GEN RQMT**	UK DWG	EAGLE	VIC	**GEN RQMT**	TAC-WAI
AD MOBILITY												
ıds explicitly modelled?	Yes	User specifies mobility	**Req'd**	Yes	No	Yes	**Req'd**	Yes	Yes	No	**Req'd**	No
nber of road classes	1	"	**16**	20	0	3	**8**	3	4	0	**4**	0
count for on-road slopes?	Yes	"	**Req'd**	Yes	No	Yes	**Req'd**	No	No	No	**Pref'd**	No
dges explicitly modelled?	No	"	**Req'd**	Yes	No	Part	**Req'd**	Yes	No	No	**Req'd**	No
dge restrictions on vehicle classes?	No	"	**Req'd**	Part	No	Part	**Req'd**	Yes	No	No	**Pref'd**	No
dge crossing rate limitations?	No	"	**Req'd**	Part	No	Part	**Req'd**	Yes	No	No	**Req'd**	No
OBSTACLES												
ers and lakes modelled explicitly?	Yes	Yes	**Req'd**	Yes	No	No	**Req'd**	Yes	No	No	**Req'd**	No
er fording locations: Explicitly modelled? Capacity attributed? Allow seasonal variation?	 Yes No Yes	 No - -	 **Req'd** **Req'd** **Req'd**	 Yes Yes No	 No No No	 No No No	 **Req'd** **Req'd** **Req'd**	 Yes Yes No	 Limited Limited Limited	 No No No	 **Req'd** **Req'd** **Req'd**	 No No No
FEATURES												
ividual buildings represented?	Yes	Poss	**Req'd**	Yes	No	No	**Req'd**	No	No	No	**Pref'd**	No
tective attributes of buildings delled?	Yes	No	**Req'd**	Yes	No	Yes	**Pref'd**	No	No	No	**Pref'd**	No
OBSTACLES												
ces restrict IV? (height given)	No	No	**Req'd**	Yes	No	No	**Req'd**	No	No	No	**Pref'd**	No
ces restrict mobility? (list icles classes)	No	N/A	**Req'd**	Yes	No	No	**Req'd**	No	No	No	**Req'd**	No
ches restrict mobility? (list vehicle sses)	Yes	N/A	**Req'd**	Yes	No	Yes	**Req'd**	Yes	No	No	**Req'd**	No
pe discontinuities restrict bility? (list veh classes)	Yes	N/A	**Req'd**	Yes	no	Yes	**Req'd**	No	No	No	**Req'd**	No
ıds restrict IV? (height given)	No	N/A	**Req'd**	Yes	No	No	**Req'd**	No	No	No	**Pref'd**	No
lroads restrict IV and mobility?	No	N/A	**Req'd**	Yes	No	No	**Req'd**	No	No	No	**Pref'd**	No
ver Lines explicitly represented?	No	No	**Req'd**	Part	No	No	**Req'd**	No	No	No	**Pref'd**	No

* Mobility characteristics are derived

TABL

TABLE III
SUPPORTING DISCUSSION FOR TABLE II
STATEMENT OF REQUIREMENTS

TERRAIN FEATURES	DISCUSSION
GENERAL FACTORS	
• Data is associated with map products at scale of 1:?	Scale should be commensurate with model class.
• Horizontal resolution: ❍ Minimum ❍ Ideal	Coy and Bn/Bde models simulate individual weapon systems and require "micro-terrain" effects to be accommodated. This forces raster data to resolutions of 10 m or less, ideally. Feature data preferably should be modelled in resolution-independent vector form as in Janus v 4.0.
• Vertical DTED resolution	Should be commensurate with the horizontal resolution, down to fractions of a meter at the Coy and Bn/Bde levels, as battlefield intervisibility is often contingent on sight lines that just graze terrain features.
• Vertical vegetation or urban height resolution	Same comments as above.
INTERVISIBILITY FACTORS	
• Direct computation of point-to-point IV using DTED?	Models that simulate individual combat systems must determine intervisibility via direct computation on the digital terrain elevation and feature data.
• Concealment: density attri-bute relating to IV horizon-tally through vegetation?	Models that compute LOS directly must accommodate degradation of target acquisition through vegetation. As all types of vegetation are not equal in hindering target acquisition, a range of density values must be accommodated.
• Cover: density attribute relating to IV down through vegetation?	Same comment as above applies to cover on air-to-ground sightlines. Depending on the height and growth of the foliage, vertical and horizontal sightlines can have distinctly different properties, necessitating separate density attributes.
• Vegetation density factors for different electromagnetic bands?	Surveillance and target acquisition sensors operate on diverse physical principles that may not be influenced in similar fashion by vegetation.
• No. of vegetation density states for cover/concealment	Variability from very thin to very dense should be provided, with finer discernment possible in more detailed models.
• Lone trees represented?	Models that simulate individual combat systems must accommodate terrain features on the same physical scale as the systems being simulated, including lone trees.
• Seasonal crop variation represented?	As many sight lines are of a grazing nature, an agricultural crop of even modest height can have a significant impact on LOS calculations.
OFF-ROAD MOBILITY	
• Density attribute relating to mobility through vegetation?	Vegetation limits the mobility of personnel and combat systems on the battlefield. Vegetation can be sufficiently variable that a range of mobility limitation values should be accommodated.
• Density factors for different vehicle classes?	Vehicles and personnel can be quite differently affected by vegetation depending on the traction mechanism, weight, size, etc.
• No. of vegetation density states for mobility	A range of mobility degradation values for each vehicle class should be provided, with finer discrimination for higher resolution models.
• Factor indicating soil nature for digging?	The ability to dig in defences is a function of the nature of the soils. Combat models should not assume that all grounds are equally suitable for digging operations.
• Cross-country mobility pre-processor inputs required: ❍ Land use code ❍ Stem size ❍ Stem spacing ❍ Soil strength ° Seasonal Variation ❍ Surface roughness ❍ Slope	Combat models, especially those with automated movement, must have realistic off-road speed predictions for each class of vehicle. Such predictions involve detailed consideration of terrain factors such as those shown to the left and the tractive properties of the vehicle class. Sophisticated mobility prediction models such as NRMM could be integrated into the combat model, but to minimize computational overhead it is recommended that maximum speed predictions be pre-processed for regions or cells on the terrain for each vehicle class and be implemented as simple look-up tables. Seasonal variation can be critical in some locations (eg. northern AS).

TERRAIN FEATURES	DISCUSSION
ON-ROAD MOBILITY	
• Roads explicitly modelled?	Roads are a critical factor in military operations, so their effect must be represented in all combat models either directly or indirectly. In models which simulate individual vehicle systems, the roads should be modelled explicitly as vector entities with mobility and capacity attributes for different classes of vehicles.
• Number of road classes	All roads are not the same from a military operations perspective. Attributes such as width, surface material, curve radius, vertical clearance, etc. determine the mobility and capacity for different classes of vehicles. A range of road types should be represented with a broader range applicable to models simulating movement at the individual vehicle level.
• Account for on-road slopes?	On-road slopes, especially in under-developed regions, can prohibit traversability by heavy vehicle systems (often support vehicles) and should be accounted for in the combat model, particularly those simulating movement at the individual vehicle level.
• Bridges explicitly modelled?	Depending on the general nature of the terrain and its (water) obstacles, bridges can be critical strategic and tactical elements on the battlefield. Their effect must be represented in sufficiently robust fashion in all classes of combat models. This includes the modelling of tactical bridging and its associated equipment.
• Bridge restrictions on vehicle classes?	The construction of a bridge can be limit the size, weight, and tractive means of vehicles that can traverse it. Because of the potentially critical role of bridges on battle outcome, these limitations must be represented in all classes of combat models.
• Bridge crossing rate limitations?	Time is a critical dimension in breaching any battlefield obstacle, as the defender can usually bring fires to bear. Bridge capacity factors must be modelled to ensure realistic crossing rates are simulated.
WATER OBSTACLES	
• Rivers and lakes modelled explicitly?	The ability of water obstacles to influence mobility makes them critical strategic and tactical elements on the battlefield. Their direct representation in all classes of combat models is required.
• River fording locations: ❍ Explicitly modelled? ❍ Capacity attributed? ❍ Allow seasonal variation?	Because of the critical influence of rivers on battlefield strategy and tactics, combat models should represent fords in a fashion similar to how they represent bridges. The same arguments above for bridge capacity factors apply for fords. Seasonal variability (water depth, ice cover) can have overriding impact on fordability, so ford attributes should be adjustable accordingly.
URBAN FEATURES	
• Individual buildings represented?	Urban settings introduce unique dimensions to land warfare. Models focusing on individual soldiers and combat systems (eg. Coy and Bn/Bde levels) must model buildings explicitly. Higher level models can aggregate the effects of urban areas on mobility and intervisibility.
• Protective attributes of buildings modelled?	Combat systems in urban areas will utilize the protective nature of buildings and other features. Models which simulate combat at the individual system level should be capable of representing this attribute.
OTHER OBSTACLES	
• Fences restrict IV? (height given)	In established agricultural regions, fences or hedgerows can represent significant impediments to ground-to-ground intervisibility. Indeed, in some European regions they can be so predominant as to become a pivotal influence on combat strategy and tactics.
• Fences restrict mobility? (list vehicles classes)	Fences of substance (eg. rock) can form effective linear obstacles to mobility for some vehicle classes. The model should handle substantial fences in a fashion analogous to how it handles streams.
• Ditches restrict mobility? (list vehicle classes)	Drainage ditches can also be a notable feature of agricultural regions, and can have a significant effect on the mobility of some or all vehicle classes. The modelling approach should be consistent with how the mobility effects of streams and fences are represented.
• Slope discontinuities restrict mobility? (list veh classes)	Off-road mobility predictions should account for average slope over a region or cell, but slope discontinuities (eg. ridges, cliffs) should be modelled as linear obstacles much like a stream, fence, or ditch.

TERRAIN FEATURES	DISCUSSION
• Roads restrict IV? (height given)	Rural roads tend to be built up in height (hence "highways"). As most ground-to-ground sight lines are grazing in nature, the elevation of intervening roadways may represent a visibility obstacle. Much like fences above, models which employ direct point-to-point LOS calculations should accommodate this p otential intervisibility factor.
• Railroads restrict IV and mobility?	Same comment as above for roads.
• Power Lines explicitly represented?	Power lines can force helicopters to higher flight altitudes in order to cross them. They also can influence the effectiveness of wire-guided missiles which cross over them. Models which simulate such systems at the individual level should model these effects in some fashion.